Commentaries

LCA and Post-hoc Application of Sustainability Criteria:

The Case of *The Natural Step**

Paul Upham

Corresponding address: Dr. Paul Upham, Research Fellow, aric aviation research group, Department of Environmental and Geographical Sciences, Manchester Metropolitan University, John Dalton Extension, Chester Street, Manchester M1 5GD, United Kingdom; e-mail: p.upham@mmu.ac.uk; internet: http://www.doc.mmu.ac.uk/aric/index.html

1 The Natural Step

The Natural Step (TNS) is promoted internationally as a framework with which to orient public and corporate decision-making towards socio-ecological sustainability. TNS licensee organisations now exist in the UK, USA, Canada, the Netherlands, New Zealand and Australia, and Japan and South Africa are in the process of establishing TNS organisations (NATRASS and ALTOMARE, 1999). In the UK, several organisations have used or promoted TNS for assessing the relative "sustainability" of products and processes (NUS UK, 1996), (NUS Services, 1996), (NCBE, 1996) and (Co-operative Bank, 1999).

TNS's core principles (*systems conditions*) are intended as a scientifically defensible, minimal representation of the requirements of sustainability, upon which all should be able to agree (ROBÈRT et al., 1997). The TNS approach has been assessed and affirmed in the abstract by US expertise, with the important proviso that it be supplemented by environmental assessment in use (NATRASS and ALTOMARE, 1999; PITCHER, 1997). TNS thinking has been examined in detail by Upham (1999a,b), and is shown to be both more challenging and rhetorical than is evident at first sight.

In the context of UK use of TNS as a product/process assessment tool, and given the scarcity of tools for product/process sustainability assessment, this commentary summarises research on the value of integrating The Natural Step with LCA. The LCA framework of SETAC (Society for Environmental Toxicology and Chemistry) is used as a term of reference, this having been largely adopted in ISO's guidance on LCA (ISO/TC 207/SC5 1996).

2 Semi-Quantitative Use of TNS in Product/Process Assessment

The decision rules included in TNS thinking (ROBÈRT et al., 1997) are listed in **Fig. 1** (→ *p. 69*). In the UK, the National Centre for Business and Ecology[1] have used the *operational corollaries* of this thinking for a brief, comparative assessment of a client's options for fire-suppressant systems (NCBE, 1996). The three options compared by NCBE are: (1) the halocarbon gas HFC-227ea (FM200™); (2) a blend of nitrogen, argon and carbon dioxide (IG-541, sold as Inergen™); (3) water; (4) the existing Halon 1301, a fluorocarbon whose replacement is banned under the Montreal Protocol (NCBE, 1996).

Fig. 2 (→ *p. 70*) shows NCBE's quick-screening estimates of impacts for each option, in terms of operational corollaries of each TNS system condition. The UK National Union of Students (NUS UK, 1996) has used TNS similarly, having adopted TNS systems conditions as criteria for self-administered, questionnaire-style environmental reviews of student union operations (NUS UK, 1996). The ethical and environment committee of their purchasing company NUS Services (1996) has also advocated TNS as a means of making initial assessments of functionally equivalent products and processes, as in **Fig. 3** (→ *p. 70*).

The ways in which NCBE, NUS UK and NUS Services have used broad indicators of impact magnitude, applying a mix of estimation, tacit and codified knowledge, is appropriate for relatively quick internal decision-making. If firms are not using other forms of environmental assessment, they are likely to find that such use of TNS will lead to enhanced environmental performance. This enhancement should not be assumed, however, for unacknowledged differences in the functional units of the process/product options may mislead the decision-maker. In Fig. 2 for example, water is judged to perform well in terms of its direct impact, but will perform less so if the analytic boundary is extended to include replacement/repair of equipment damaged as a result of its use. Similarly, in Fig. 3, the wooden floor performs well because it is thought to involve less encroachment (spatial displacement) and energy usage than concrete. This may well be so at the extraction and production stages, but if both options are sent to landfill at the disposal stage, the wooden floor will decompose to produce methane, contribute to global warming, and hence reduce its (probable) relative environmental benefit.

Moreover, rule-of-thumb forms of TNS use do not incorporate any explicit notion of sustainability limits, and as such render TNS primarily an environmental rather than sustainability guide. This is because they are not explicitly framed by TNS's injunction for absolute limits on environmental resource usage. These limits are not self-evident, but

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[1] NCBE (Salford, UK) is a not-for-profit company founded by four universities in the region, and the Co-operative Bank, for the purpose of raising the environmental performance of small to medium sized businesses in the locality, through its own consultancy and the use of university staff and post-graduate student expertise.

System Condition 1 *Substances from the lithosphere must not systematically increase in the ecosphere.*
Rate corollary 1 - *This means:* in the sustainable society, fossil fuels, metals and other minerals must not be extracted and dispersed at a faster pace than their slow redeposit and reintegration into the Earth's crust.
Operational corollary 1 - *In practical terms, in relation to today's situation, the consequences are:* radically decreased use of fossil fuels, and mining - particularly of scarce elements that are accumulating already today, e.g. cadmium.
Operational question 1 - *Can your organization, municipality or country systematically decrease its economic dependence on lithospheric metals, fuels and other minerals?*
System Condition 2 *Substances produced by society must not systematically increase in the ecosphere.*
Rate corollary 2 - *This means:* in the sustainable society substances must not be produced and dispersed at a faster pace than they can be broken down and integrated into the cycles of nature or be deposited into the Earth's crust.
Operational corollary 2 - *In practical terms, in relation to today's situation, the consequences are:* decreased production of natural substances that are accumulating systematically, and a phasing out of persistent unnatural substances.
Operational question 2 - *Can your organization, municipality or country systematically decrease its economic dependence on persistent unnatural substances?*
System Condition 3 *The physical basis for the productivity and diversity of Nature must not be systematically deteriorated.*
Rate corollary 3 - *This means:* in the sustainable society we cannot harvest or manipulate the ecosystem in such a way that productive capacity and diversity systematically deteriorate.
Operational corollary 3 - *In practical terms, in relation to today's situation, the consequences are:* sweeping changes in our use of productive land in, for instance, agriculture, forestry, fishing, and planning of societies.
Operational question 3 - *Can your organization, municipality or country systematically decrease its economic dependence on activities which encroach on productive parts of nature, e.g. long distance road transport or other deleterious exploitation of green surfaces, over-fishing etc.?*
System Condition 4 *Fair and efficient use of resources with respect to meeting human needs.*
Rate corollary 4 - *This means:* in the sustainable society basic human needs must be met with the most resource-efficient methods possible, and their satisfaction must take precedence over luxury consumption.
Operational corollary 4 - *In practical terms, in relation to today's situation, the consequences are:* increased technical and organizational efficiency throughout the whole world, including a more resource-efficient lifestyle, particularly in the wealthy sectors of society. Furthermore, it implies improved means of dealing with population growth.
Operational question 4 - *Can your organization, municipality or country systematically decrease its economic dependence on using unnecessarily large amounts of resources in relation to added human value?*

Fig. 1: TNS principles and corollaries Robèrt et al. (1997, 85-87)

follow from TNS's prohibition of any systematic, human-induced biospheric accumulation of non-biospheric material. This prohibition is emphasised by TNS's strict demand that the rate of material inputs to the human economy (the *technosphere*) should not exceed the rate of waste material output from that economy (ROBÈRT et al., 1997). TNS intends these and related injunctions as goals to be reached over time, and to represent a posited end-state of sustainability. If they are not understood or are neglected for their high degree of practical difficulty, TNS is reduced to a basic screening guide when used for product/process assessment. That TNS is able to function in this role is due to its general identification of anthropogenic environmental damage processes.

3 Use of The Natural Step Rationale as a Basis for LCA Impact Categories

Integrating TNS with formal LCA rules would in principle increase its reliability in product/process assessment, but such integration is demonstrably problematic. The first problem is that the criteria of systematic accumulation and deterioration in TNS systems conditions 1-3 (→ *Fig. 1*) are not easily related to the production of a single functional unit in LCA, since accumulation and deterioration are processes and hence are only observable over time. One "solution" is to use the TNS rationale, specifically the anthropogenic environmental damage processes that TNS identifies, to inform LCA impact categories. These damage processes are reflected in TNS's operational corollaries (e.g. *reduce use of lithospheric material*), so that corresponding LCA impact categories could be:

1. Use of lithospheric material
2. Use of other persistent material
3. Damage to the physical basis of biodiversity and natural productivity
4. Inefficiency of resource use.

In this list, equity is omitted from consideration for practical reasons only. In fact, the categories do not relate directly to impact, but to precursors of impact, in reflection of the pressure nature of TNS. In principle, the categories as a set should subsume the much larger list of LCA impact categories proposed by the Society for Environmental Toxicology and Chemistry (SETAC) (UDO DE HAES, 1996a).

Comparison with a different understanding of TNS's integration with LCA, by Andersson et al. (1998), shows how

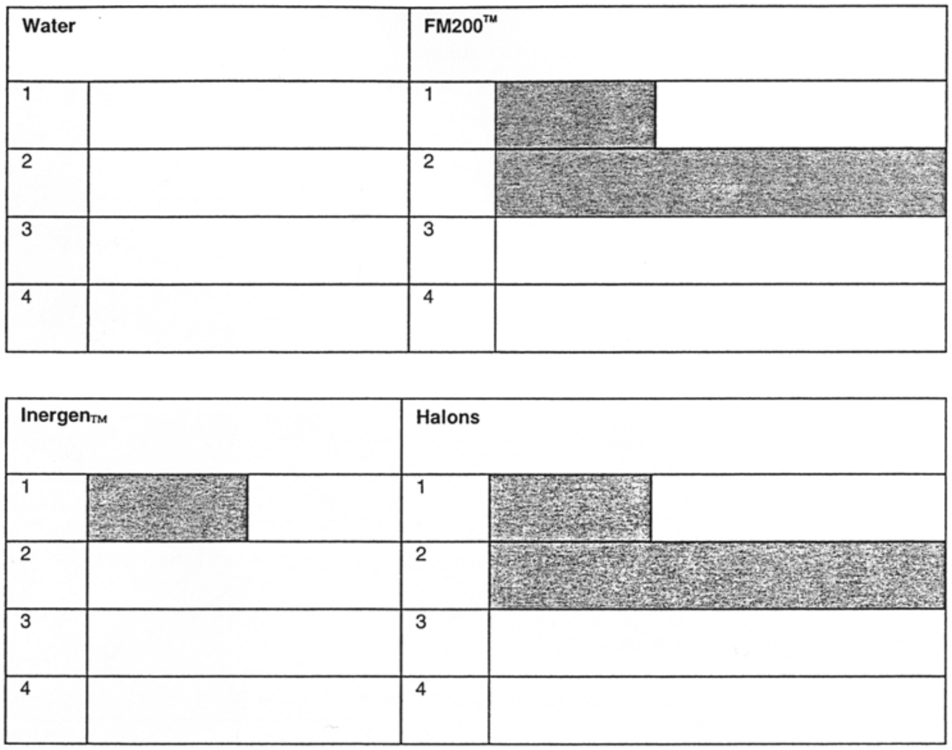

Fig. 2: Simplified impact assessment with operational corollaries of The Natural Step (NCBE, 1996)

Note: Rows 1-4 represent the operational corollaries of the TNS systems conditions that are used to screen the four fire-fighting products. In each row, estimated impact is proportional to the length of the shaded area. Row (1) represents use of lithospheric material, row (2) use of persistent synthetic material, row (3) spatial encroachment on natural areas and row (4) inefficiency and social inequity.

"A new floor is required by your first-floor events venue, with a long-term seal to conform to legal safety and hygiene standards.

Option 1
Wooden floor, double-boarded with closely spaced battens for fastening, covered with sealed plastic. Half of the quote is for labour costs, and half is for materials. Cost £7,000.

Option 2
Concrete floor, several tons of which will be needed, covered with sealed plastic. The concrete will be delivered and pumped through a first floor window directly into the floor space required. The quote is almost solely for materials costs. Cost £6,500.

Option 2 violates systems conditions 1, 2 and 3, as substantial mining and transport are involved, as well as the immensely polluting process of manufacturing cement. Thus the productivity of the Earth is reduced through the devastation surrounding cement factories and aggregate mines.

Option 1 violates system condition 2 only, as the wood can be selected to be produced from sustainably managed forests, thus satisfying system condition 3.

Aside from considerations of the weight and strength of the floor, checking the two options against the 4 systems considerations shows that both options violate system condition 2. There is at present probably no sealant that doesn't use persistent man-made substances, so the only option is to seek out the best practice sealant available.

Option 1 is arguably a more efficient use of resources (system condition 4) as less energy is required in the manufacture of floorboards than concrete.

The sustainable choice of floor is therefore undoubtedly the wooden floor, option 1. This analysis must now be compared against other factors of consideration before installing the floor."

Fig. 3: Hypothetical use of TNS by a Purchasing Company (NUS Services, 1996)

TNS differs from assessment guides that have fixed characteristics and rules in use, whether codified in software, text or cognitively by consistent judgement. Andersson *et al* (*ibid*) see no need to explain how they move from a statement of the TNS systems conditions and their operational "corollaries", to a set of more detailed impact categories. Thus for system condition two, they propose: global warming potential (CO_2 equivalent) for 100 years; ozone depletion potential; eutrophication (oxygen depletion, maximum scenario); acidification (level of hydrogen proton release); photo-oxidant formation (photochemical ozone creation potential, as ethene-equivalent); human toxicity (substance weighting

factors for kg release to air, water and soil, developed by CML [Centre for Environmental Science], Leiden University) (ANDERSSON et al., 1998: 294).

There is nothing intrinsically "wrong" with these impact categories. However, their use involves reference to points that can be conceived of as either further along the impact cause-effect chain, or as corresponding to lower levels of impact aggregation. In turn, this means the loss of the high aggregation and pressure-level components of TNS. TNS is not formulated at the level of impact or effect, but of anthropogenic activity, as at the pressure stage of a *Pressure-State-Response* (PSR) model of environment-economy interactions (OECD, 1998).

Departure from a high aggregation level, as by Andersson *et al* (1998), increases the extent of nominal use of TNS in LCA, leaving TNS as an organising framework without any discriminatory function. While the same is true of SETAC's *safeguard subjects* – Resources, Human health and Ecological health (UDO DE HAES, 1996a) – SETAC does not propose these as a means of discriminating sustainable from unsustainable actions. Moreover, the consensual potential of TNS is partly dependent on its high level of aggregation: the more specific a statement, the clearer its implications, and the greater the opportunity for disagreement with it.

4 Inventory Indicators for TNS Impact Categories

TNS's high level of aggregation and lack of indicative guidance allows direct inference of only broad, inventory-based indicators, each of which is limited in its indicative value. The first mooted impact category relates to use of lithospheric material. The life cycle indicator that most closely reflects this is simply mass of *extracted lithospheric material used*, where this is the total input and waste output of material originally lying beneath the upper layer of soil supportive of shallow-rooting vegetation.

The second TNS impact category relates to persistent "unnatural" compounds. Given the number of chemicals involved, indicating this term at its own level of generality is likely to involve significant value judgement. One option is to restrict indicators to those persistent, synthetic substances listed for priority control by statutory regulation. However, use of priority lists based on risk assessment involves levels of analytic detail that the TNS seeks to avoid. This reflects an ambiguity in TNS thinking. *Level II* risk assessment (i.e. that based on anthropogenic concentration rise) is preferred by TNS advocates (ROBÈRT et al., 1997). Yet, *Level III* risk assessment (determination of relative toxicity, persistence and associated thresholds) is necessary to identify the persistence that TNS identifies as significant (*ibid*). TNS thinking eschews Level II ostensibly because of the uncertainty of critical thresholds (ROBÈRT et al., ibid), but also because related contentions are of the sort that Robèrt (1991) considers as obstacles to sustainability.

Inconsistency notwithstanding, the *mass of substances on the current EC Black and Grey Lists* (Business in the Environment, 1997) is a possible indicator for the second TNS impact category. This unavoidably entails a double counting of the lithospheric portion of the mass, and neglects changes to substances as they are partly broken down post-emission. TNS offers no way to justify the choice of this particular priority list, and the substances on the list have been selected on toxicity grounds as well as bioaccumulation potential and persistence (European Commission, 1976).

The third TNS impact category relates to damage to the physical basis of biodiversity and natural productivity. Indicative options include classifications of anthropogenic landscape change such as ***hardening of the surface area*** (Andersson et al., 1998), and *area of land occupied* as proposed in the Sustainable Process Index (KROTSCHECK and NARODOSLAWSKY, 1996), excluding the waste dissipation term (op. cit.) to reflect TNS's avoidance of critical thresholds.

The fourth TNS impact category relates to efficient use of resources in meeting human needs. Given TNS's (partly rhetorical) thermodynamic emphasis (ROBÈRT et al., 1997), there is justification for seeking to express the first and second laws in the fourth, as well as preceding impact categories. Following Wall (1986), *exergy loss or consumption* is proposed as a measure of the depletion and use of resources, and hence of the efficiency of resource use.

5 Conclusion: Use of TNS Norms as Post-hoc LCA Sustainability Criteria

TNS brings little, additional technical value to LCA. In practice, even those who might use a developed version of TNS as an LCA screening tool are unlikely to have ready access to data on land use and consumed exergy. This would leave the TNS/LCA integration as consisting of life cycle input and waste output mass inventory "indicators" for lithospherics and priority list chemicals, which takes LCA back to a state not much further developed than the MIPS (SCHMIDT-BLEEK, 1993).

Normatively, however, TNS has more to contribute. Firstly, TNS's injunction for reverse planning (backcasting) requires a committed, iterative search for ways of meeting needs in ways that progressively reduce environmental impact. For example, Robèrt (1995) implies that companies should seek to influence conditions that lead to LCA supporting practices that appear environmentally sub-optimal, such as hypothetical LCA support for plastic over paper bags.

Secondly, TNS's requirement for a present-level curb on non-biospheric inputs, waste outputs and biotic impact, regardless of corporate ambitions for growth (UPHAM, 1999a,b) has implications for the purposes to which LCA is put. Effectively, TNS means that growth in the physical aspects of economic activity is permissible only through use of biomass, cultivated and processed so as to enhance global biological productivity (ibid.). Unless this criterion is satisfied, firms committed to TNS should only market new products or services if sufficient input, waste output and biotic damage savings have been made elsewhere in their operation. LCA could, theoretically, assist in estimating the magnitude of those savings and hence the quantity available for new product or service lines. It could also assist in estimating the current, total input, waste output and biotic impact beyond which the firm is not to grow. Used in this way, TNS norms could frame LCA methods that *do*

meet SETAC's protocols, to function as post-hoc sustainability criteria. Whether there are any firms that are genuinely willing to accept TNS's challenge, however, is debatable.

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LCA in Greece

An LCA-active research group has been established at the Department of Environmental Studies of the University of the Aegean. Within this group, a number of graduate and undergraduate students are currently working on topics related to Life Cycle Assessment, Eco-design and Environmental Management.

Overview of Ph.D. dissertations, projects and research papers that are in progress:

Ph.D. Dissertations:

1. Development of Life Cycle Assessment and Design for Environment: Methodologies for the Automobile
   Petros Grimanis
2. Development of an Life Cycle Assessment Methodology based on Societal, Cultural and Educational Parameters
   Helen Syrrakou
3. Development of an Life Cycle Assessment Methodology for Local Authorities
   Andreas Triantafyllou
4. Development of an Life Cycle Assessment Methodology for Landfill Sites
   Yannis Yannakis

Other Projects:

1. Life Cycle Assessment of Feta Cheese Packaging
2. Life Cycle Assessment of Olive Oil Packaging
3. Life Cycle Assessment of Photovoltaics
4. Life Cycle Assessment of Wind Turbines
5. Eco-design of Packaging Materials
6. Environmental Management in the Dairy Industry
7. Environmental Management in the Cement Industry
8. Environmental Management in the Hotel Industry

Dr. Adamantios Skordilis, Hellenic Ministry for the Environment, Physical Planning and Public Work and University of the Aegean; e-mail: pgri@env.aegean.gr